Predicting residual strength in unsaturated concrete exposed to sulfate attack

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Abstract: Deleterious damage that manifests in cracking and strength loss due to expansion and exfoliation often occurs when hardened concrete is exposed to sulfates. For a degradation-free service life, modeling sulfate attack is as important as considerations for strength and stability in concrete. This paper focuses on modeling the impact of gypsum as a constitutive durability product responsible for strength loss in concrete due to sulfate attack. The model blends the calculation of coupled moisture-sulfate transport processes with quantitative simulation of chemical reactions involving sulfates, moisture, and an incipient portlandite phase in concrete. Account is taken of variations in sulfate and moisture diffusivities to reflect microstructural changes when a portlandite matrix is stoichiometrically transformed to gypsum. Implementation of the model to both water-saturated and unsaturated concretes is numerically achieved according to standard Galerkin procedure in the finite-element sense. Contrary to expectations, simulation results for the case of initially unsaturated specimens before immersion in a sulfate solution are not significantly different from the initially saturated condition. Calculations of global relative residual strength predicated on degradation profiles generated by the model showed good agreement with postsulfate-immersion-test residual strength data.